but the shell is not ribbed, and otherwise differs. In some respects it resembles *Geomelania*; but the shell, again, is smooth, and covered with an olive epidermis, like that of *Acicula* and *Tomichia*. The animal, however, certainly does not agree with *Tomichia*, which I have lately had an opportunity of observing in two Japanese species, nor with *Acicula*, if, indeed, this genus has been correctly described.

Dr. Pfeiffer, in his account of *Acicula*, observes, "Eyes on the upper part of the head; tentacula subulate;" and Dr. Gray says of the same genus, "Eyes on the back of the head, between and rather behind the base of the tentacula." The figure of *Acicula fusca*, copied from Hartmann by my brother and myself, in our 'Genera,' has subulate tentacles; and the same is the case with my figure of *Truncatella* in the same work, which was taken from a very lively individual which I had in my possession for some time. If I had only observed a stray example of *Cecina* in confinement, I should have thought the animal was sick, and that the tentacles were contracted; but I have seen hundreds crawling about the damp rotten logs, after I had turned over the latter for the purpose of watching the habits of these strange little mollusks. They resemble *Truncatella* in their mode of progression—fixing their long muzzle and dragging their shell and body close up to the fixed point, and then, fixing in turn their short foot, advancing the muzzle for another stride.

Shanghai, China,
Jan. 15, 1861.

XXXIV.—*Further Observations on the Structure of* Foraminifera, *and on the larger Fossilized Forms of Scinde, &c., including a new Genus and Species.* By H. J. Carter, Esq., F.R.S.*

[Plates XV. XVI. & XVII.]

Since my observations on the structure of *Operculina arabica* and my description of some of the larger forms of fossilized Foraminifera in Scinde were published, in 1852† and 1853‡ respectively, many valuable contributions have been made to our knowledge of the structure and species of the Foraminifera, amongst which those that I shall have to refer to most here are MM. le Vicomte d'Archiac and J. Haime's 'Monograph on the Nummulites§,' and Dr. Carpenter's 'Memoirs' on the structure

* Communicated by the Author, having been read before the Bombay Branch of the Royal Asiatic Society, April 11, 1861.—A brief summary of the results was given in the September Number of the 'Annals.'

† Ann. & Mag. Nat. Hist. ser. 2. vol. x. p. 161. ‡ *Ib.* vol. xi. p. 425.

§ Description des Animaux Foss. du Groupe Nummulitique de l'Inde. aris, 1853.

of *Orbitolites*, *Orbiculina*, *Cycloclypeus*, *Heterostegina**, and *Operculina*†, because they have enabled me most to correct, add to, and explain what I have already stated respecting the Foraminifera,—it being easily conceived that, in a branch of knowledge like this, which is still in its infancy, every contribution that is worth anything will probably more or less revolutionize that which has preceded it, at the same time that it will claim for its author that consideration for his errors and omissions which such progressive knowledge demands.

It might be asked, why I do not write complete editions of my papers, instead of giving simply corrections, additions, &c. My reply is, that I have not time to do this now, and therefore record what I have to offer for the use of others for this purpose, or for my own use on some future occasion, as the case may be.

Needing then no other introduction than this, I will only further premise (as much of what I have already stated has been denied) that, in my paper of 1852 on the structure of *Operculina arabica*, to which was added an illustration of an infiltrated Nummulite (*N. acuta*), showing that the canal-system was the same in both, I observed that the former would "elucidate all that has hitherto been stated of, and leave little to be added to, the general structure of foraminiferous shells, both recent and fossil;" and I am glad to be able to add now (viz. ten years since this observation and my description of the structure of *Operculina* were written), that I have not stated in either anything which I wish to recall. Since then, however, Ehrenberg has confirmed what I have described and illustrated respectively of the canal-system in *Operculina* and *Nummulites* (viz. in *Nummulites striata*, in 1855‡); and lately I have been able to repeat this myself most satisfactorily in another of the *Striatæ*, viz. in *N. Ramondi* (mihi), as I shall show hereafter.

I would also mention here my regret that, in my paper on the structure of *Operculina arabica*, I did not observe that Professor Williamson had previously pointed out the existence of the canal-system in part, viz. in the marginal cord of *Nonionina* §. This arose from ignorance of the fact; for I never have been able even up to this day to obtain the volume of the 'Transactions of the Microscopical Society of London' (1st ser. vol. iii.) in which it was published; while that on *Faujasina*, by the same author, which points out the "intraseptal canals" of this system, although read in 1851, was not published by that Society until 1853 (2nd ser. vol. i.), that is, a year after my paper on *Operculina arabica* appeared in the 'Annals and Magazine of

* Phil. Trans. part i. p. 181, and part ii. p. 549, 1856.
† *Ib.* p. 1, 1859.
‡ Phil. Trans. 1859, p. 28.
§ *Ibid.*

Natural History;' and hence the reasons for Prof. Williamson's discovery having been omitted.

Further Observations on the Structure of Foraminifera.

Operculina, D'Orbigny.

In Dr. Carpenter's elaborate and valuable paper on the structure of this genus, taken from specimens of *Operculina arabica* originally obtained from the Philippine Islands, he has made an important addition to what I have stated on the subject in one respect, and anything but one in another, inasmuch as he has denied the spicular structure of the marginal cord, which is one of the most palpable objects in the test.

The important fact that he has added is the discovery, in the canal-system, of a main spiral trunk, which commences with the spire, in duplicate (that is, one in each horizontal half of the test), and follows it to its termination. These two large trunks, to which Dr. Carpenter has applied the name of "spiral canals," he states, "though only running along the angles of the marginal cord, pretty obviously communicate with the plexus of passages which it contains; and thus the interseptal system of one whorl is brought into direct connexion with that of the preceding*." To complete this description, I would add that, in the first two or three turns, the interseptal canals form a *direct* bond of union between the spiral canals, but afterwards only by some of their branches, as the interseptal canals then go to the inner side of the marginal cord, where they divide into branches, and the great spiral canals remain continuous outside, at the point of junction of the spiral lamina and the cord.

I had observed these canals, as may be seen by my illustration (fig. 5, *loc. cit.*), where the interseptal canals of the outer whorl are represented as springing from one of them, but had not specially recognized them as they deserved, and as has now been very fortunately done by Dr. Carpenter. But MM. D'Archiac and Haime had recognized and figured them, without knowing what they were, even before this, in *Nummulites planulata* (pl. 9. fig. 7, p. 63), where they state, with reference to "the grooves" in the marginal cord, "Une seule espèce (*N. planulata*) offre de chaque côté du bourrelet un sillon environ cinq fois plus large que tous les autres. Les canaux moyens s'ouvrent presque toujours dans ces sillons." No doubt, therefore, exists in my own mind, from having also seen them in a closely allied Nummulite, viz. *N. Ramondi* (Pl. XVII. fig. 15*ff*), that the "sillons" represented in the figure mentioned are the "spiral canals" described by Dr. Carpenter in *Operculina*.

* Phil. Trans. 1859, p. 28.

On the other hand, the more important fact, which Dr. Carpenter has failed to recognize after my description of it, is the spicular structure of what he terms the "marginal cord," which had been previously named by myself the "spicular cord," to denote its peculiar composition, and under which appellation, although I like the former name much, I must still continue to allude to it.

I need hardly quote all that Dr. Carpenter has stated respecting the structure of this part of the test of *Operculina*; suffice it therefore to notice that he considers its structure homogeneous, and not spicular. Thus he observes, "the supposed spicular composition of this 'marginal cord' (as it may be appropriately termed) is due to the peculiar manner in which the homogeneous substance of which it is composed is traversed by the set of canals that are correctly described by Mr. Carter as forming the 'marginal plexus *.'"

Now, I would rather not have had to repeat what I stated respecting the structure of this cord ten years since; and I feel certain that, if Dr. Carpenter had taken a favourable specimen of *Operculina*, and with a small, sharp scalpel had cut off tangentially portions of this cord, there would have been no occasion for it. However, these subjects seldom lose by a second investigation, and the result of mine in this instance is, that I am not only more convinced of the spicular structure of the cord than ever, but am now able to describe its composition much more definitely than has hitherto been done.

Thus, this cord, which is almost semicircular, with the arch or convex part outwards and the chord or base within, is composed of—1st, spicules; 2nd, an interspicular substance; and, 3rd, a plexus of anastomosing canals (Pl. XVII. fig. 11).

The spicules (fig. 10) are semitransparent, homogeneous, crystalline, calcareous bodies, more or less fusiform in shape, and arranged one above another irregularly and interdigitatingly, in horizontally inclined planes, which, like the leaves of a book when open, radiate partly from the centre of the "chord" and partly along this chord on either side—that is to say, they do not all radiate from a common point; while there are also a certain number of semiplanes at the circumference, which fill up the intervals formed by the radiating of the whole ones (fig. 11 *e*).

The interspicular substance is an areolar, calcareous, membranous structure, which unites the spicules together and the planes to each other respectively. It resembles and is analogous to the albuminous tissue which surrounds and unites the spicules in the spiculiferous Sponges.

Lastly, the plexus of anastomosing canals consists of reticu-

* Phil. Trans. 1859, p. 25.

lated planes of these canals which lie between the planes of the spicules (fig. 11 *d*), the canals of which anastomose with each other through the spicular planes, communicate with the interseptal canals, and open on the surface of the cord respectively.

In some, if not in all, specimens the spicules not only exist throughout the cord (for they can be seen on its inner aspect, where the cord is in contact with the outer margin of the chambers), *but are continued inwards over the interseptal spaces almost to the centre of the Operculina.*

Now, if the substance of the cord were homogeneous, the structures mentioned in it could not be defined. If it were simply the "peculiar manner" in which its homogeneous substance were "traversed by the set of canals" which it contains, as stated by Dr. Carpenter, then portions of the cord, on transverse fracture, could not be made to present the ends of spicules at the fractured points, nor could portions of the cord fall out, on fracture longitudinally, in the form of spicules. Nothing but certain portions of the cord being harder than the rest, and these portions being of a spicular form, could give rise to either of these appearances; while if it be the "peculiar manner in which the homogeneous substance of which it is composed is traversed by the set of canals" which gives the cord an appearance of spicular structure, how is it that this spicular appearance exists over almost all the interseptal spaces of some specimens where there is no plexus, and no canals but a few short ones which pass through it almost perpendicularly? It is, however, useless to have recourse to argument for conviction when the fact can be demonstrated; so we will turn our attention to another point in the economy of this shell, viz. the "canal-system."

As regards the use of the canal-system, nothing yet has been definitely assigned. I formerly thought that it subserved the purpose of a water-circulation, as in Sponges,—viz. the water going in by the ends of the small canals which open on the horizontal surface of the test, and coming out through the orifices of the larger ones on the surface of the spicular cord; and I now think that this may be a part of their function, at the same time that they may draw in nutritious particles by the small pores also, like the Sponges. The anastomosing canals, resembling also in appearance and function the mycelium of Fungi, serve to convey portions of the sarcode (upon which the canals themselves are first moulded) to the points from which new portions of the organism are to be developed, while they undoubtedly, too, in part, perform the office of excretory channels; for in the recent and living specimens of *Operculina arabica* which I obtained on the coast of Arabia, the sarcode of the interseptal canals, after the calcareous matter of the test has

been removed by acid, remains in connexion with the membranous chambers by short branches, through which globular bodies (to which I shall more particularly allude presently), that are more or less present in the chambers, readily pass, on pressure, into the larger interseptal canals; and again through these, probably by the openings on the spicular cord, during the living state, they would have obtained an exit. That the sarcode of the canal-system also carries on the development of the organism independently of the chambers, is proved by the development of the test continuing after the chambers have ceased to be formed, as will also be hereafter mentioned.

Lastly, the substance covering the horizontal surface of the test, which I have likened to the cuticle of shells, in accounting for the formation of the horizontally-laminated structure of the test, and have inferred to be connected with the sarcode of the chambers through its vertical tubuli, MM. d'Archiac and Haime have more properly likened to the "épiderme des échinides ou de l'épithèque des polypes" (p. 69). But what I meant is seen by the context in my paper, viz. that, in its dry state, it was merely *like* the cuticle of shells in appearance, and not identical with it.

Of this substance Dr. Carpenter states nothing in his paper on *Operculina*; but in his description of *Orbitolites* he observes, in a foot-note (p. 207), "I have little doubt that 'the greenish' cuticle described by Mr. Carter as covering his *Operculina arabica*, and supposed by MM. d'Archiac and Haime to be specially connected with the formation of the shell, is of the same nature," that is, of the nature of "a covering of vegetation, chiefly composed of Diatomaceæ, Desmidieæ, and other minute Algæ." To which I must simply reply that "such a mistake is impossible with a practical microscopist." Moreover, lately I have had to examine some "deep-sea soundings" from the Arabian Sea, in which there were many minute Foraminifera; and as it is at such depths that the Foraminifera are most likely to be taken up alive, or with the living sarcode of the animal in their tests, so most of these were covered with the so-called "cuticle" first seen on the substance of *Operculina arabica*.

But are not the horizontal or "spiral" laminæ (as they have been termed by D'Archiac and Haime, in *Nummulites*) of *Operculina* composed almost entirely of vertical tubuli which establish a direct connexion between the cavity of the chambers and the surface, and between the chambers of the overlying layers in *Nummulites*? Is not the sarcode which fills the cavities of the test of *Operculina*, &c., like that of the Rhizopoda generally, whose portions flow together when they come in contact; and would they not thus form a layer over the surface of the

test? And could the horizontal layers of the test be formed in any other way, or are they likely to be so, under such circumstances? Lastly, is not all this in favour of what I have stated, viz. that there is a substance in appearance like the "cuticle" of shells, over the dried specimens of Foraminifera which contained the living organism when they were taken out of the water? But, as I have already observed respecting the spicular structure of the cord, the fact does not rest upon argument, but can be demonstrated; and upon demonstration I made the statement ten years ago!

The "vertical tubuli," as just stated, connect the chambers with the surface, not only in *Operculina*, but in the tests of *Nummulites*, *Orbitoides dispansa*, and *Orbitolites Mantelli*; and it is through their agency chiefly that the layers of shell and the chambers are vertically formed.

The openings on the horizontal surface over and about the septal spaces are those of canals connected with the great interseptal system. They are the same as MM. d'Archiac and Haime's "canaux d'une troisième grandeur," or middle-sized canals."

But, besides these openings, there are spaces and lines in *Operculina* which are composed of shell-substance alone, that is, without the presence of the vertical tubuli or the middle-sized canals; and these in the test of the recent *Operculina* have the appearance of homogeneity and transparency, but are opake and white in the fossilized one, where they evidently are identical with the opake-white portions of *Nummulites*, which have afforded MM. d'Archiac and Haime some of their chief distinguishing characters; and thus the latter are proved not to be what they supposed them, viz. remains of "larges canaux," but, originally, transparent portions of the shell, unaccompanied by any canal, except accidentally, as will be more particularly shown hereafter.

Animal of Operculina.—Hardly anything more of the animal of *Operculina* is known now than when my description of the test was published; and I now, as then, cannot help thinking that the existence of the animal matter of the *Robulina* which I examined at sea, and thought to be in the form of a worm in "loops" in the chambers, united by constrictions where the chambers joined, close to the spicular cord, was a fallacy; for the observations were made at sea, in a little vessel, on the deck, in the open air, with simple though powerful lenses; and since then, all that I have been able to obtain from the specimens of *Operculina* which had living animals in them when they were taken, is a number of membranous sacs, corresponding in form with that of the chambers, and united by a like membranous

structure at the base, where the latter are in contact with the spire or spicular cord,—united also with the membranous tubes of the interseptal canals—those of the marginal plexus on both sides, those which unite the chambers themselves together across the interseptal spaces, and, lastly, others which unite the chambers with the vertical tubuli which open on the horizontal surface of the test.

Besides this, the chambers have generally been more or less filled with minute, spherical, nucleated bodies, the note of whose size I have mislaid, similar to those which I have described and figured in the freshwater Rhizopod called "*Euglypha*," and which I have considered to be embryonal cells (Ann. Nat. Hist. ser. 2. vol. xviii. pl. 5. fig. 26, and vol. xx. pl. 1. fig. 19*b*, &c.), which, again, are like those figured by Dr. Carpenter in the cells of *Orbitolites* (Phil. Trans. pl. 4. fig. 3), and which he views as the sarcode broken up into propagative "gemmules." My own view of them in *Operculina* also is, that they are propagative bodies of the species. But the most interesting point which their presence in the chambers of *Operculina* has elicited with me is that by slight pressure they can be easily made to pass through the short channels of communication which exist between the chambers and the interseptal canals, into the latter,—showing thus, as before stated, that one of the uses of the interseptal canals is to give exit to these bodies through the branches of the marginal plexus which open on the surface of the last or outermost turn of the spicular cord.

The bond of union between the chambers at the spicular cord is not tubular; or, at least, I never saw the propagative spherules pass from one chamber to the other through it, while I am inclined to think that this bond is chiefly composed of the sarcodal plexus of the spicular cord, and that from *this* the chambers are developed, as will be better understood presently—also that the part of the plexus which is more directly concerned in uniting the chambers occupies the free surface of the spicular cord, and gives rise to that arched opening which exists between the septa and the spicular cord. The free margin of the septum here also frequently presents a scolloped form, as if it had rested on a plexus of sarcodal filaments, while in some cases I have not been able to distinguish any aperture between the septum and the cord at all, indicating that the two are sometimes in contact. All this seems to show that the chambers are developed from the marginal plexus, and not from each other.

As regards the function of the chambers, the presence of the nucleated spherules above mentioned in them seems to indicate that they are the reproductive organs; and the fact that in *Alveolina elliptica* they are frequently almost wanting altogether,

while in other instances they are interrupted two or three times by several turns of the cortical part alone (which part is analogous to the spicular cord of *Operculina*), and that in the globose Nummulites the chambers are frequently not distinguishable in the outer turns, shows that the development of the test can go on without the presence of the chambers, and therefore that they are probably supplementary and propagative. Indeed, the approximation of the turns of the spire, or those of the spicular cord, which, of course, must entail a corresponding diminution in the size of the chambers, will be found by-and-by to indicate the full size of the species, in which the subsidence of the generative force appears to be thus indicated.

As yet, however, we know very little about the animal of Foraminifera, chiefly because we are so ignorant of the forms allied to it. The same is the case with the animal of *Spongilla*, which I have described (Ann. Nat. Hist. vol. xx. 1857). It fails to elicit much attention because, at present, it has no known alliances; but by-and-by, when these are found out and more forms of the same kind are discovered for comparison, the nature and position in organic development of these beings will be realized and their component parts understood. Till then they must remain in abeyance.

Mode of growth.—The mode of growth in *Operculina* and *Nummulites* is the same; that is, the horizontal portions, or spiral laminæ as they have been termed by MM. d'Archiac and Haime, are developed from the sarcode of the chambers passing through the vertical tubuli, while the spicular cord and the chambers in the first instance spring from the marginal plexus of sarcodal filaments. The latter is shown in *Alveolina*, as above stated, where the chambers cease to be developed and then appear again after several turns of the spire have been completed by the cortical layer alone, which part, as before stated, is analogous to the spicular cord. Both the segments of *Operculina* and those of *Nummulites* begin to be formed from the spicular cord, and three or more of the last are generally in successive stages of development, the last of all being the least formed. This must not, however, be confounded with the last chambers of the fully-developed *Operculina*, which, like those of *Nummulites*, are also successively less in size.

More recent Observations.—Since the above was written, I have again determined, for examination, to sacrifice two or three more of the few specimens I still possess of *Operculina arabica* containing the living animal when they were brought up with the "sounding-lead," on the south-east coast of Arabia, in 1844, now of course dry; and for this purpose one of these was placed in very weak spirit and water for a night first, another examined

at the moment of being broken up in water, and a third subjected to a very weak solution of nitric acid and water for a night, with the following results:—

It was found that, in the latter experiment, the chambers and the canals, after having been gradually deprived of their calcareous matter, still retained their form in a membranous state (Pl. XVII. fig. 12); and under this condition they will now be described.

Chamber.—The horizontal or exposed walls of the chamber, in a membranous state, present a number of semi-opake circular bodies arranged in a pavement-like form close together, each of which has a depression or hole in the centre, and these correspond to the "vertical tubuli" (fig. 12 *a*, *b*); while the septal borders (*c*) are composed of a transparent membrane without these bodies, but pierced here and there with large holes (*f f*); from which tubes are extended to the interseptal canals. The marginal border of the chamber is also supplied by a transparent membrane loosely attached to the spicular cord, but the base or internal margin is firmly fixed to the marginal plexus of canals, now, of course, in the way we are examining them, all rendered membranous by the absence of the calcareous matter.

The chamber thus reduced to a membranous state is found to contain in its cavity various bodies (fig. 11 *e*), viz. small and large spherules (figs. 13, 14), and starch-grains, to which we will now severally direct our attention.

Small spherule (fig. 13).—This consists of a spherical portion of semi-opake homogeneous matter, surrounded by a delicate spherical transparent cell, 1-5400th of an inch in diameter. The chamber may contain a few only, or be crammed with these bodies; and they are observed to be attached in masses to branched stems or filaments, like bunches of grapes.

Large spherule (fig. 14).—The large spherule consists of a spherical portion of homogeneous matter charged with granules and enclosed in a spherical transparent capsule about 1-1800th of an inch in diameter. The capsule is not always visible, if present, and the form frequently slightly elliptical, while the colour is sometimes yellowish by transmitted light, like that of dried albumen, and at others white by reflected light, as if there were calcareous matter in it; perhaps the former difference may be from drying or pressure, while the latter is evidently that of advancement in development.

Starch-grains.—These are thin, flat, and variable in size, but otherwise bear the unmistakeable characters of the "starch-grain." They were not numerous, but always present, and, with many portions of the other soft substance of the cavity of the chamber, became purple and blue respectively, under the

influence of the deliquescent yellowish liquor of iodide of potassium assisted by a little sulphuric acid.

Canal-system.—The canals (fig. 11 *d*) having been deprived of their calcareous matter, became equally membranous with the chamber; and those portions forming a communication between the chamber and the "interseptal canals" freely admitted the largest spherules to pass through them from the former to the latter (*ff*); besides this, I find a number of them, in one of my dried specimens without the animal, in all parts of the canal-system.

From these facts we learn that there are two kinds of spherules produced in the chambers, the larger of which appear to be but an advanced state of the smaller; but whether this be the correct view, or that the smaller ones are the sperm-cells or some other organ belonging to the chamber, remains to be shown. That the large spherules cannot be viewed in any other light than as propagative bodies, there can be no doubt now; but whether, again, these are impregnated or unimpregnated reproductive agents also remains to be shown. That they are the same with what I have already pointed out as the reproductive agents both in the *Euglyphæ* and in *Amœba verrucosa* (*loc. cit.*) appears also to me to be undoubted.

The next fact is, that the passage of these bodies freely from the chamber into the interseptal canals proves that one use at least of the canals is, as before stated, to give exit to the contents of the chambers.

Lastly, the presence of starch-grains, although not wonderful, as the organism is distinctly a Rhizopod, and starch-grains abound in *Spongilla*, especially in the capsules, is nevertheless interesting, as their presence also in the winter-eggs of the fresh-water Polyzoa and the close resemblance of this "egg" to the capsule of *Spongilla* thus make the presence of starch-grains in all, one point, at least, which so far allies these organisms. Not only this, but the resemblance of the canal-system, or rather the sarcodal filaments which it contains, to the mycelium of Fungi, as before noticed, and the evident connexion that also exists between *Spongilla* and some of the parasitic developments of the cell-contents of the Algæ (now properly regarded by Pringsheim as allied to *Achlya* and *Saprolegnia*)—whose spores, first consisting of monociliated polymorphic cells, then lose their cilium and become simple Rhizopods, while other developments of this kind are distinct Fungi putting forth sporangia with defined, cell-walled sporules,—seem to point out the passage of the animal into the fungal kingdom through the Foraminifera and Sponges. The parasite to which I more particularly allude is that termed by Pringsheim *Pythium entophytum*, which grows out from the

cell-contents of *Spirogyra*, and in its sporangia produces the monociliated spores mentioned, which, in 1857, I described as furnishing an instance of the "transformation of the vegetable protoplasm into *Actinophrys**," forsaking my original argument that these products *must* be parasitical, which Pringsheim's discoveries have now confirmed†.

Besides the course which the spherules have for their exit through the canal-system, some of my recent specimens present a hole here and there at the base of the few last chambers, opposite the great spiral canal, in which holes the large spherules, now white, may be seen, as if in the act of being voided, and probably from the great spiral canal. A single large hole, with a smooth margin, evidently formed by the animal itself, also appears here and there, sometimes, in the side of the chambers; and this may have been for the purpose of giving exit to young *Operculinæ* which had become too large to obtain their issue in the ordinary way, such as those noticed by Prof. Schultze in the *Rotalidæ* (Ann. Nat. Hist. vol. vii. p. 306, 1861) and also by Dr. S. Wright (*ib.* vol. vii. p. 357). But both these kinds of holes must be regarded as accidental, and not as regular developments of the test.

Nummulites.

The structure of the test of *Nummulites* is precisely that of *Operculina, plus* the lateral or vertical growth of the former, which is but a repetition, in plan, of the horizontal plane. Of this I was aware in 1852, when my description of the structure of *Operculina* was published, and my diagram of an infiltrated specimen of *N. acuta* (Ann. Nat. Hist. *l. c.*), to confirm this, accompanied it. Since then, as before stated, the "canal-system" has been figured by Ehrenberg from an infiltrated specimen of *N. striata*; and within the last twelve months I have been able to see everything which I have described in the test of *Operculina* exemplified in richly infiltrated specimens of another of the *Striatæ*, viz. *N. Ramondi*, accompanied by equally richly infiltrated specimens of *Operculina*; so that the means of identification has, through the latter, been most satisfactory.

Canal-system.—The lateral or vertical development of *Nummulites* being the only additional part to the horizontal plane as it exists in *Operculina*, I have merely to state concerning the canal-system of this, that radiating branches are continued upward towards the centre or umbilicus of the Nummulite from the great "spiral" canals of the cord, or from others near this, along each interseptal space, and from each turn of the

* Ann. Nat. Hist. ser. 2, vol. xix. p. 259.

† Ann. des Sc. Nat. xi. p. 349, pl. 7, Bot. 1859.

cord; that vertical branches also, from each turn of the cord opposite the interseptal spaces respectively, keep up a communication (by joining the radiating branches of the different layers of the spiral lamina) between the marginal plexuses of the turns of the cord and the surface; and that, in some Nummulites, where there is a transverse division in the portions of the chambers extending up towards the centre, corresponding with the turns of the spire, the radiating branches are connected by transverse ones; so that, in fact, each chamber is surrounded by an anastomosing circle of canals thus formed, while, in the reticulated Nummulites, this anastomosis becomes retiform from the reticulated division of that part of the chambers which enters into the composition of the spiral lamina. Lastly, the canal-system sends off branches which open on the surface in the course of the interseptal spaces and along the spiral canals, as in *Operculina*. Thus in each lamina of the Nummulite the canal-system of the horizontal plane is repeated.

Vertical tubuli.—These enter into the formation of each spiral lamina just as they do into the single one of *Operculina*.

Non-tubular spaces.—Such are parts of the test which are not traversed by either the vertical tubes or the branches of the canal-system, and, as before stated, in recent *Operculina* are marked by a homogeneous semitransparency of the shell-substance, while in the fossilized species they are opake and white, —a transition which leads to the knowledge of what they are and were in *Nummulites*. They may be linear, radiating, or sinuous, as when forming that part of the test over the interseptal spaces, or punctiform, as when in the midst of the vertical tubuli, and in both positions afford signs, according to their form and number, for specific distinction. In *N. biaritzensis* these white parts may be seen to form also a minute branch-work, which extends perpendicularly outwards from the septal lines; and in *N. perforata* a similar branchwork may be observed to spread both from the septal lines and the puncta (very like the lacunæ and their branchwork in bone), but to such an extent in some specimens as to present a minute reticulation all over the cameral spaces, so much resembling a capillary canal-structure, that, at first sight, there seems to be no doubt of it. However, their being formed of an opake-white substance like the septal lines and the puncta first leads to the opinion that they are not tubes; and this is confirmed by microscopical examination of portions of the spiral lamina of *N. perforata* presenting this structure, when ground down to a thinness sufficient to allow the light to pass through them; for besides the absence of any double line indicative of the presence of a tube in these white lines (which are then found to be made up of little dis-

joined portions of opake material), a lash of branches from the "canal-system" may here and there be observed to come through one of the puncta, and spread out among these white lines, when the double line and transparency indicative of a continued canal in them, at once, and by contrast, shows the nature of both. Thus, from what has been stated, we see that neither the white puncta nor the minute white branchwork of lines were ever tubular. In most Nummulites the white puncta appear on the surface, and, when examined in a vertical section of the Nummulite, are observed to be more or less conical, and of different lengths according with the date of the commencement of their development, those which began with the earliest parts of the Nummulite being longest. They arise in points from the surface of the chambers and the interseptal spaces, and end at the periphery, on a level with the rest of the test; but, being harder than the latter, they project on weathering, become rounded, and thus give the fossil a more or less granular surface. Now, in none of these white lines, white puncta, nor minute white branchwork, have I ever been able to see any indication, either in recent *Operculina*, the fossilized infiltrated one, or in *Nummulites*, of any branches of the canal-system, except by accident. Neither in the ends of the columns in *Orbitoides dispansa*, which are the same as those of Nummulites, have I, in the most richly and minutely infiltrated specimens, been able to see, in the ends of the white columns on the surface, any red or yellow point indicating that they are always in connexion with a branch of the canal-system which traverses them longitudinally. So we must set these portions down as having nothing to do with the canal-system, however much they may conduce to the strength of the test.

Thus we see that the "très-petits canaux" of MM. d'Archiac and Haime (p. 60) were the "vertical tubuli;" their "canaux moyens" the openings of the canal-system on the surface and along the spiral canals and spicular cord; and their "larges canaux" no canals at all, but the ends of the columns of condensed shell-substance. Dr. Carpenter, who also at first considered the latter canals, renounced this view long ago (Phil. Trans. 1856, p. 553, *foot-note*).

Spicular cord.—The same infiltrated specimens of *N. Ramondi* which were obtained from the Rajpipla Hills, a little south of the river Nurbudda, near Broach, that have latterly furnished me with such beautiful confirmations of *Nummulites* possessing the same canal-structure as that in *Operculina*, have afforded almost as much evidence of the spicular composition of the cord; for, besides being accompanied with equally beautiful infiltrated specimens of *Operculina* for comparison, they are all imbedded

in a yellow argillaceous limestone, in such a way that, by careful fracture, they fall out with surfaces so polished and even, that their preservation, thus far, may be said to be complete; and hence the marking on the surfaces respectively is most evident. We, therefore, have only to put the margins of *N. Ramondi* and this *Operculina* together, and bring them into the focus of a microscopic power, to see that those on the cord of the *Operculina* are a facsimile of those on the cord of recent *Operculina arabica*, which we know to indicate a spicular composition, and that those on the cord of *N. Ramondi* are precisely like those of the fossilized *Operculina*, with the exception that the lines are less interrupted in the cord of the Nummulite, and are therefore, continuously, much longer, which indicates much longer spicules; but the fact of all the spicules not being of the same form or of the same length in the same species, or of different lengths generally in another most closely allied organism, to wit *Nummulites*, does not affect the verity of the spicular composition of the cord. Indeed, writing of these lines as supposed grooves, MM. d'Archiac and Haime state (p. 63), "Les sillons, dont le nombre et le degré de rapprochement varient un peu, sont sensiblement droits et continus dans la plupart des cas, mais quelquefois (*N. lævigata*, pl. 4) ils sont très légèrement flexueux, et assez fréquemment interrompus." The latter is the case with the lines on the cord of *N. Ramondi*; and the same interruptions or terminations, in a *pointed* form, I have observed in *N. spira*.

Further, on comparing the cords of the two fossils mentioned, viz. *Operculina* and *N. Ramondi*, we observe a number of red points in the lines or intervals between the spicules, which are nothing more than red oxide of iron filling the canals of the marginal plexus in both the Operculina and Nummulite, which open on the surface of the cord. Thus the identity in structure and composition of the surface of the spicular cord in *Operculina* and *Nummulites* is so far complete. But we have still the interior to identify, which, as far as the layers (planes of spicules in *Operculina*) radiating from the inner side of the cord to its circumference go, even to their being constricted at intervals into a number of short portions, and the planes of the canal-system between them, I have been able to see in the *N. spira*, *N. sublæviyata*, and *N. Ramondi*, both in the transverse and horizontal section of their cords respectively; still not the remotest trace of the circular or the horizontal lines of the spicules in either the one or the other of these sections have I seen. When, however, it is remembered that, although I have preparations to show distinctly the linear contours of the spicules in the horizontal section of the cord of *Operculina arabica*, and therefore can infer the existence of the circular lines which they must present

in the transverse section with certainty, though I have not yet succeeded in making a preparation to show them so satisfactorily in the transverse section (nor can they be demonstrated either in the horizontal or transverse section in fossil *Operculina* under the most favourable circumstances, although they no doubt did exist there, any more than in *Nummulites*), it is not to be wondered at that they should not be demonstrable in *Nummulites*, where crystallization and fossilization must have more or less blended these structures into one mass. But, with the surface-identity mentioned, the presence of the planes of opake matter in the transverse section of the cord (which represent the planes of spicules in *Operculina arabica*), divided partially at short intervals by transverse constrictions (which in *Operculina* define the ends of the spicules), and the transparent planes or intervals in which are seen the truncated ends of the great horizontal canals of the canal-system in recent *Operculina*, I think we have here quite sufficient to enable us to infer that the cord in *Nummulites* was generally of the same composition as that of *Operculina arabica*, but with the spicules much longer; that is to say, that the cord was composed of the same kind of materials: viz. 1st, the crystalline matter of the spicules; 2nd, the interspicular substance; and 3rd, the canal-system. To arrive at this conclusion, however, it is necessary to be first well acquainted with the spicular cord in recent *Operculina*, then to compare this with fossil *Operculina*, and lastly, to compare the latter with *Nummulites*, all of which must be in specimens favourable for the purpose,—since a mere section of the cord of *Nummulites* would inevitably be met with a denial of its spicular composition, so little appearance is there in it of spicules.

Moreover, the "great spiral canals" of the cord of *Operculina arabica*, to which I have alluded at the commencement, and which are evident also in the cord of *N. Ramondi* (though not so evident, if existing at all, in *N. sublævigata*), did not escape the penetrating and sagacious observation of the authors of the "Fossiles de l'Inde;" for they, as I have previously shown, not only figure the openings of the marginal plexus, but also the two great spiral vessels of the cord in *N. planulata*, and describe them in the words which have been already quoted.

Yet, in their work, MM. d'Archiac and Haime have stated (p. 54), "Nous nous sommes assurés, par des observations très multipliées, que dans aucune des espèces de ce dernier genre [*Nummulites*] il n'existe rien qui puisse rappeler la corde spiculaire ni le plexus marginal signalés par M. Carter dans l'Operculine d'Arabie." Had the lamented naturalist whose name is last mentioned been alive, he, with his noble colleague, would now have admitted that what I stated, and showed in a figure,

ten years since, at least as regards the existence of the marginal plexus in *Nummulites*, was correct. It has been admitted by Dr. Carpenter (Phil. Trans. 1859, p. 26), although he also still denies the spicular structure of the cord, but will not do so any longer, I think, after seeing my preparations. Dr. Carpenter has, however, long since marked out the skeleton of the spicular composition of the cord, as will be seen by the grooved lines on the surface and the radiating ones in the transverse section, represented respectively in his figures of *N. lævigata* (figs. 17 & 15, pls. 4 & 5, Quart. Journ. Geol. Soc. vol. vi. 1850). At the same time it should be remembered that the longitudinal grooves do not always indicate spicules, but circumscribe spaces which can be seen under a much lower power than the spicules.

Propagative spherules.—So recent must have been the infiltrated specimens of *N. Ramondi* when they were imbedded, that even the spherules, assumed to be propagative gemmules or embryonal cells in *Operculina arabica*, are exquisitely preserved in a fossilized state in many of the chambers of the former, where they are all spherical in shape, but vary in size, below the 1-2800th of an inch in diameter (Pl. XVII. fig. 15 *e*). They are not only found to exist in every part of the chamber up to the umbilicus of the Nummulite, but in the primary chamber itself, and may be not only seen in every part of the canal-system, but (the smaller ones) also in the vertical tubes of the spiral lamina, on their way out. In the infiltrated specimens of *Orbitoides dispansa* they also abound throughout both the chambers of the central plane and the columnar chambers, even to the centre of the fossil (fig. 1 *o*). I have also seen them in the chambers of *Orbitolites Mantelli*, *Orbitolina lenticularis*, and in *Alveolina elliptica*; and thus occurring so generally, there can be no longer any reasonable doubt that they are what I have assumed them to be, viz. "propagative agents," but whether the product of impregnation or of simple generation, remains for further research to determine. In one section of *N. Ramondi* which I possess (for I have sections by me to prove everything that I have stated), there is a spherule in one of the chambers of the last turn which has thrown out a second one, with a Nautiloid form of test around it, indicative of *Nummulites* being occasionally viviparous, as before stated to have been noticed in the *Rotalidæ* by Prof. Schultze (Ann. Nat. Hist. *l. c.* p. 320).

Mode of growth.—This, like that of *Operculina*, is simply spiral, with the chambers continued up to the centre or umbilicus of the Nummulite. The development of the chamber commences from the spicular cord, and extends outwards and inwards from this point; but it is not fully formed for some time afterwards; so that there are several always present in successive stages of

completion, from the chamber just budding to that one extending from the margin to the umbilicus. This gradation is also a consequence of age or full development of the Nummulite, there being a gradual diminution in size from the largest chamber to the primary one on one side, as there is from the largest to the last-formed one on the other: hence the circular form of *Nummulites*. The same has been stated of *Operculina*; but here the termination is generally more abrupt, which causes the test to assume a somewhat elliptical form.

Classification of Nummulites.—On this subject I have but few observations to offer, after the able one proposed by MM. d'Archiac and Haime (p. 72), viz. 1st, *Læves aut Sublæves*; 2nd, *Reticulatæ*; 3rd, *Subreticulatæ*; 4th, *Punctulatæ*; 5th, *Plicatæ vel Striatæ*; and 6th, *Explanatæ*. What I have to state, however, will be chiefly found under the descriptions of the species which have elicited it respectively.

The dividing of the Nummulites which present a reticulated structure on the surface from the rest, which I proposed (Ann. Nat. Hist. p. 164, 1853), was being carried into effect by MM. d'Archiac and Haime for their second and third groups at the time I was writing my MS. in India. So it is evident that I was not single in suggesting this,—although I made a mistake, as they notice (p. 343), in attributing the suggestion to Dr. Carpenter in the first instance, whose proposition, on the other hand (Quart. Journ. Geol. Soc. *l. c.* p. 30), was to make the *Assilinæ* a "sub-genus" of *Nummulites*. But as regards MM. d'Archiac and Haime's dividing the reticulated Nummulites into two groups, and the changing of the name *Assilina* to *Nummulites* respectively, I think it would have been better to have made but one group of the former, as noticed by Messrs. Parker and Jones (Ann. Nat. Hist.), and not to have changed the name of the latter, for reasons which will be hereafter mentioned.

Again, as regards my observation that the reticulated Nummulite *N. acuta*, Sow. "borders close upon *Orbitoides*," MM. d'Archiac and Haime observe (p. 343), "Il n'y a pas plus de passage entre cette Nummulite et l'organisation des *Orbitoides* (*O. dispansa*) qu'entre tout autre corps de ces deux genres." I was wrong certainly in stating that there was a commencing degradation of the spire in *N. acuta* into the horizontal plane of *Orbitoides*, but no further; for, as will be seen, the external appearance as well as the internal structure of *O. dispansa* approximates it to the reticulated Nummulites more than to any other discoid Nummulite. Thus, the thinness of the margin, abrupt elevation of the centre, and reticulated structure of the lateral masses are especially characteristic of both, although the abrupt elevation may not always be present in either. The

columnar structure, viz. the "larges canaux" of D'Archiac and Haime, is particularly developed in the reticulated Nummulites, and is analogous to that of *O. dispansa*, although not so much developed. But, as will be seen by-and-by in *Orbitoides*, the rows of chambers in the horizontal plane are cyclical, which is a character of *Orbitolites*, and not of *Nummulites*. This, then, makes *O. dispansa*, although it more than all the other large discoidal Foraminifera approaches the reticulated Nummulites, distinctly differ from them. It will be observed further on, that the structure of *Orbitoides dispansa* compels us to view it as merely a *Cycloclypeus* with lateral growth; and Dr. Carpenter, who has studied the latter, observes (Phil. Trans. 1856, p. 563), that while *Cycloclypeus* agrees in most points with *Nummulites*, it only differs from it essentially "in the single circumstance that the mode of increase is cyclical instead of helical;" so that we have here still further, though indirect, confirmation of what I have before stated, viz. that *N. acuta* "borders close upon *Orbitoides*." As to the defective state of my figures (Ann. Nat. Hist. vol. xi. pl. 7, 1853) misleading the authors of the "Fossiles de l'Inde," it should be remembered that they bear on their faces evidence that they were only meant as diagrams, and that, in India, we have not only frequently to find the objects themselves, but to make sections of, and draw them before we describe them, and sometimes to lithograph them; and therefore that it would be fairest to judge from the descriptions, as they are most likely to be correct, seeing that we have neither such means nor such men to make sections, drawings, &c., for us in India as can be obtained in Europe.

Alveolina, D'Orb.

Of this genus I have nothing to state here further than that the tubular cortical structure appears to me to be analogous to the spicular cord and its canal-system in *Nummulites*, and the chambers to both the horizontal plane and those parts of the chambers which are lengthened out towards the poles or lateral eminences in *Nummulites*. As before stated, *Alveolina* looks to me like a flat Nummulite drawn out in each direction laterally, and has its transitional form in the globose Nummulites. Never having had a highly infiltrated specimen, I cannot state what the minute structure of its canal-system is, nor whether the cortical layer, which corresponds to the spicular cord of *Nummulites*, contained any spicules; but I should think not, and that the canal-system was replaced by the tubular structure of the cortical layer. As before stated, spherules have been observed in *A. elliptica* in its innermost chambers.

The species of *Alveolina* (viz. *A. Boscii*) described and illus-

trated by Dr. Carpenter (Phil. Trans. 1856, p. 552) is totally different from Parkinson and Sowerby's *Fasciolites elliptica*, which is the type of the *Alveolina* of Scinde, and of which I have given illustrations (Ann. Nat. Hist. 1854, vol. xiv. p. 99); while the new species, which I have described further on, under the name of *A. meandrina*, is again so different from either and from any other existing description, that at first sight it seems doubtful whether it should not form the type of a new genus. On examining it internally, however, it is found that its chambers, although tortuous like those on the surface of *N. gyzehensis*, &c., commence in a spiral form as simply as those of *Operculina*, but instead of remaining subsigmoid, as in *A. elliptica*, become tortuous, while there is a reticulated canal-structure arching over each, and supported on vertical tubes connected with a similar structure over the preceding layer, which, when viewed longitudinally in a vertical or horizontal section, appears to correspond to the tubular structure arching over the chambers and interseptal canals respectively of *A. elliptica*, which structure, again, corresponds, as before stated, to the spicular cord and interseptal canals of *Operculina* and *Nummulites*.

Orbitoides, D'Orb.

In this family two distinct genera have been included, viz. *Orbitoides dispansa* and *Orbitoides Mantelli*, D'Orb. (*Orbitolites Mantelli*, Cart.), as will be seen by their descriptions hereafter under their respective heads. Moreover, it will also be seen there that they are so different that they can hardly be included even in the same family: at least, while the former is closely allied to *Cycloclypeus*, Carp., the latter is so closely allied to *Orbitolites* that I proposed the name of "*Orbitolites Mantelli*" for it, instead of "*Orbitoides*" (Ann. Nat. Hist. vol. xi. p. 174, 1853). Whether this was a better name than its original one (that is, than "*Orbitoides Mantelli*") I will not stop to discuss now, but go on to notice the structure of these two fossils respectively and summarily, referring the reader to a more detailed description of them under their proper heads. The detail of their anatomy has been obtained from richly infiltrated specimens in which, as in the Nummulite and Operculina mentioned, the red or yellow oxide of iron so completely fills up the cavities of the test which were originally occupied by sarcode, while the rest remains more or less transparent and white, that sections of the fossil in this state give a much better view of these cavities than could be obtained from the test were it present in its unfossilized condition and occupied by the living animal. Following are the summary descriptions of them respectively.

Orbitoides dispansa (Pl. XVI. fig. 1, &c.).—The test of this

discoidal fossil consists of a horizontal plane of *oblong* chambers covered in on each side by a mass of columnar ones. The chambers of the horizontal plane are in circular rows, concentrically arranged around a central globular cell, which may be large or small. [Formerly I stated that they began "multispirally," and gave a figure (Ann. Nat. Hist. ser. 2. vol. xi. pl. 7, p. 26) to prove it; but I have since found that this was drawn from a section of a minute *Heterostegina* which I had mistaken for an *Orbitoides*.] Each chamber is connected with the two immediately behind and before it respectively by stolon-processes; and the chambers generally increase in length in the radial direction of the test with their distance from the centre, up to a certain point, when their vertical diameter preponderates over their horizontal one, not from increase of the former, but from diminution of the latter, following, therefore, the same law that is observed in *Nummulites*. The columnar chambers, on the other hand, are arranged in convex layers arching over the horizontal plane; each chamber is compressed vertically, varies in shape and size, and is united to those immediately around it by stolon-processes. Interspersed between the columnar chambers are a number of columns, of a conical shape, having their pointed ends on the horizontal plane and their large extremities on the surface; these consist of non-tubular condensed shell-substance, which is opake and white in the fossil, and are analogous to the white columns in *Nummulites* and similar structures in recent *Operculina*. Vertical tubuli exist throughout the horizontal layers of shell-substance, as in *Nummulites*; and there is a double horizontal canal-system, consisting of a single layer of network tubulation on each side of the horizontal plane, whose meshes are parallelograms, and enclose respectively one of the oblong chambers. One cannot help seeing here a part, at least, of the canal-system of *Cycloclypeus* (Phil. Trans. 1856, pl. 29. fig. 11). Whether it be from the smallness of my specimens (which, however, are $\frac{4}{12}$ to $\frac{8}{12}$ inch in diameter) or the smallness of the canal-system (but I think the former, from the remnants of this system being most evident in the largest ones), no other part of the canal-system which has been described by Dr. Carpenter in *Cycloclypeus* appears to be developed in them.

Orbitolites Mantelli, Cart. (Pl. XVI. fig. 2, &c.).—This discoidal fossil consists of a horizontal plane of *globular* chambers, which become cylindrical externally and are covered in on each side by a mass of columnar ones. Those of the horizontal plane are in circular rows, concentrically arranged around a central one, and are *not* connected by stolon-process, but *attached* to sarcodal canals, as will be mentioned directly; they also increase only slightly in their horizontal diameter with their distance from the

centre, while they so increase vertically as to become cylindrical, and thus cause the horizontal plane to be much *thicker* at the circumference than in the centre. The columnar chamber-structure is exactly the same as in *Orbitoides*, but there are *no* columns of condensed white shell-substance. Vertical tubuli exist throughout the horizontal layers of shell-substance, as in *Nummulites*. The canal-system is composed of two sets of sarcodal channels, which permeate the test. The first consists of *radiating* horizontal ones which spread off spirally, like the lines on an engine-turned watch-case, from the centre to the circumference; these are arranged in layers, commencing with two (?) in the centre, which are separate from each other, but whose lines, crossing in their course to the circumference, after the manner mentioned, unite *separately* with the chamber which is fixed in the internal angle of the interspaces that they thus form; afterwards they become doubled and trebled as the chamber lengthens, so that at the circumference each chamber becomes connected with six of such canals, and six openings appear between the chambers, at the margin of the test, in zigzag, one above another. The second set consists of *annular* horizontal canals, arranged concentrically in two layers only, viz. one on each side the horizontal-chamber layer, on a level with the ends and between the rows of chambers respectively with which they are united on the inner side: also a subsystem consisting of much smaller canals, one set of which connects the annular bands horizontally between the chambers; another connects them vertically, through the horizontal plane; and the third, only seen occasionally, seems to ascend vertically from the annular canals of each side to be lost in the interspaces between the columnar chambers. Here also one cannot help seeing the sarcodal system of *Orbitolites* given in Dr. Carpenter's diagram (Phil. Trans. 1856, pl. 5. fig. 6); but I do not see that scolloped form of the annular bands in the infiltrated specimens which appears in the uninfiltrated ones (Pl. XVII. fig. 2 *o*), and is represented by Dr. Carpenter as bearing the chambers in *Orbitolites*; nor do I see the stolon-process coming from the *convexities* of the scollops to form the chambers of the next row outwards, unless the faint transverse radiating lines of the "subsystem" be these (Pl. XVI. fig. 2, *l* 2). Further, Dr. Carpenter (p. 222) only allows a single layer of annular bands in the simple type of *Orbitolites*; and assuming that the horizontal plane of *Orbitolites Mantelli* commences in the same way, we might assume that it also possesses only a single layer; but the minuteness of the structure in the central part almost defies this decision in my specimens.

The reader will now have seen the differences between *Orbi-*

toides dispansa and *Orbitolites Mantelli*, and their correspondences respectively with *Cycloclypeus* and *Orbitolites*. He will also have seen how, partly following D'Orbigny's description of the latter genus, I fell into the error of changing the name of "*Orbitoides Mantelli*" into *Orbitolites Mantelli*, now evidently an ill-chosen one,—although it should not be called "*Orbitoides*," whose position I shall more particularly assign presently.

It is also questioned by MM. d'Archiac and Haime if this *Orbitolites Mantelli* be the *Orbitoides Mantelli*, D'Orb., of the United States (Tab. p. 363). Yes: it corresponds with the figures given by Dr. Carpenter (Quart. Journ. Geol. Soc. *l. c.*) of this fossil, which are too faithful to be mistaken.

CONULITES, nov. gen. Pl. XV. fig. 7, &c.

This beautiful little discoidal fossil, which appears to me to have hitherto been undescribed, and upon which the genus is therefore founded, was discovered among a number of Nummulitic fossils from the valley of Kelat, which were sent to me by Dr. Cook, after whom I have named the species, in commemoration of his indefatigable and successful exertions on behalf of geology in that locality. It is not, however, confined to the valley of Kelat; for I had specimens, imbedded with Nummulites, by me from Scinde, one of which, being a vertical section in a polished pebble of nummulitic limestone, always puzzled me before I recognized the fossil in its free state, while, being partially infiltrated with yellow oxide of iron, it has since enabled me, more than any others, to describe the internal structure. This, together with the external form of the fossil, will be found fully detailed further on, under its proper head, and therefore all we need here is a short generic summary of its description, which is as follows:—

Gen. char.—Conical, compressed, discoidal; consisting externally of a spiral layer of rhomboidal chambers extending from the apex to the circumference; filled up internally with convex layers of compressed columnar chambers interspersed with white columns of condensed shell-substance; white columns opake, conical, their sharp ends resting on the inner aspect of the spiral layer, and their large ones terminating at the base of the cone, which presents a slightly convex granular surface.

It will thus be seen that while *Conulites*, in its conical form, external layer of chambers, and internal columnar chamber-structure is analogous to *Orbitolina* generally, but more especially to the solid conical forms, it, in possessing the white columns of condensed shell-substance, is also allied to *Orbitoides*, while it differs from the latter and agrees with *Nummulites* in the spiral arrangement of the layer of chambers externally. Hence

it becomes questionable, after all, whether the cyclical and helical characters are of much use in classification; but to this point we will return again after having alluded to the other genera of Foraminifera in which I shall have to describe species.

Orbitolina, D'Orb.

Of this genus I have nothing to add more than is stated under the species which I have described.

Cyclolina, D'Orb.

This now appears to me to be a species of *Orbitolina*, which, had it been better defined by D'Orbigny, would have saved me from much error, as will be observed by my "Observations" under the head of "*Orbitolites pedunculata*" at the end.

Heterostegina, D'Orb., *and* Cycloclypeus, Carp.

Under these names respectively will be found a description of the specimens of *Heterostegina* and *Cycloclypeus* which, with *Orbitolites Mantelli*, I found together on the south-east coast of Arabia.

Of the former I have nothing to add here; but as regards *Cycloclypeus*, from existing specimens of which Dr. Carpenter has given his excellent description and illustration of the genus (Phil. Trans. 1856, p. 555, &c.), one cannot help seeing, in the oblong form of the chambers, the irregularity of the rows, their cyclical arrangement, their vertical thickness diminishing towards the circumference, each chamber being connected with two behind and two before it, the canal-system, and, lastly, the conical non-tubular parts of the test, which resemble the columns, that *Cycloclypeus* approaches *Orbitoides dispansa* as nearly as *Operculina* approaches *Nummulites*.

In my description of the minute structure of *Orbitoides dispansa*, I have stated that I was not able to see such an elaborate disposition of the canal-system; but then the size of the recent specimens of *Cycloclypeus* examined by Dr. Carpenter, and their structure generally, far exceeding, in both, the infiltrated specimens of *Orbitoides* in my possession, may partly, if not wholly, account for this.

For further observations on the specimens of *Heterostegina* and *Cycloclypeus* which have come under my notice, see their descriptions respectively.

Orbiculina *and* Orbitolites.

The exhaustive and valuable researches of Dr. Carpenter on these two genera, given in the 'Philosophical Transactions' for

1856, preclude the necessity of my making any further observations on them beyond what will be found under the species which I have had to describe.

Classification.

I would here merely observe that, as regards family distinction, it appears to me that *Orbitoides dispansa, Conulites, Heterostegina,* and *Cycloclypeus* should come together under one head, and *Orbitolites Mantelli,* Cart., *Orbitolina, Orbiculina,* and *Orbitolites,* as defined by Dr. Carpenter, under another. Perhaps it will be stated that the spiral form of the layer of chambers in *Conulites* should place it with *Nummulites,* among D'Orbigny's "Hélicostègues," irrespective of its being in every other way most closely allied to *Orbitoides,* which belongs to the "Cyclostègues;" and hence the doubtful value of the helical and cyclical characters as natural distinctions, to which I have before alluded.

Conclusion.

Having thus made all the prefatory observations that I have to offer at present on the different genera of Foraminifera, whose species I shall now have more or less to describe particularly, let us proceed to this part of the subject, remembering, as before stated, that my object *now* is solely to correct, add to, and explain what I have hitherto stated, and that, therefore, much will be found in my paper in the 'Annals' of 1853, to which I have alluded, which is omitted here. It will be also necessary for the most part, too, that the reader should provide himself with copies of MM. d'Archiac and Haime's 'Monograph on the Nummulites' and Dr. Carpenter's "Researches" in the 'Philosophical Transactions,' respectively; for they are so necessary for the study of the Foraminifera, that it is impossible to get on without frequent reference to them.

Among the new forms that I have had to introduce will be found two varieties, viz. *a* and *b* of *Assilina seu Nummulites exponens,* and one new species, viz. *A. obesa,* belonging to the *Explanatæ*; one new species belonging to the *Punctulatæ,* viz. *N. broachensis*; two species to the *Plicatæ vel Striatæ,* viz. *N. makullaensis* and *N. kelatensis*; one species to the *Reticulatæ,* viz. *N. masiraensis,* and an undetermined one from the coast opposite; one new species of *Alveolina,* viz. *A. meandrina*; and a new genus and species, viz. *Conulites* and *C. Cookii* respectively; one variety, if not a new species, of *Orbitoides,* viz. *O. asterifera*; and perhaps some new forms of *Orbitolina.*

[To be continued.]